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Considerations in Source $PM_{2.5}$ Measurement Methodology Development for Industrial Combustion Emissions

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Conference on
"$PM_{2.5}$ and Electric Power Generation:
Recent Findings and Implications"
DOE/NETL

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Fine PM Emission Research Consortium

- Environment Canada
- Ontario Power Generation
- TransAlta Corporation
- Natural Resources Canada
- 3-phase program
  - Oil-fired boiler
  - Pilot-scale coal-fired boiler
  - Field-ready for utility boilers

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Technical Challenges

- Simulation of plume conditions
- Isokinetic sampling & automatic control
- Ambient comparable PM analysis
- Field suitability
- Integrity of emission data

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Simulation of Plume Conditions

- Source dilution is common approach
- 20-40 times provides ambient-like temperatures
- Larger dilution requires large system, impractical
- Limited study showed positive effect of dilution on PM mass
- What about NH_3 and UV ?

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Isokinetic Sampling & Automatic Control

- Stack velocity to accommodate varying unit sizes
- Residence time vs dilution ratio vs tunnel size
- Turbulent mixing of flue gas and dilution air
- Automatic control and balance of flows that are very different in magnitude
- Accurate measurement of dilution ratio
- On-line RH control
- Dilution air supply and pre-cleaning

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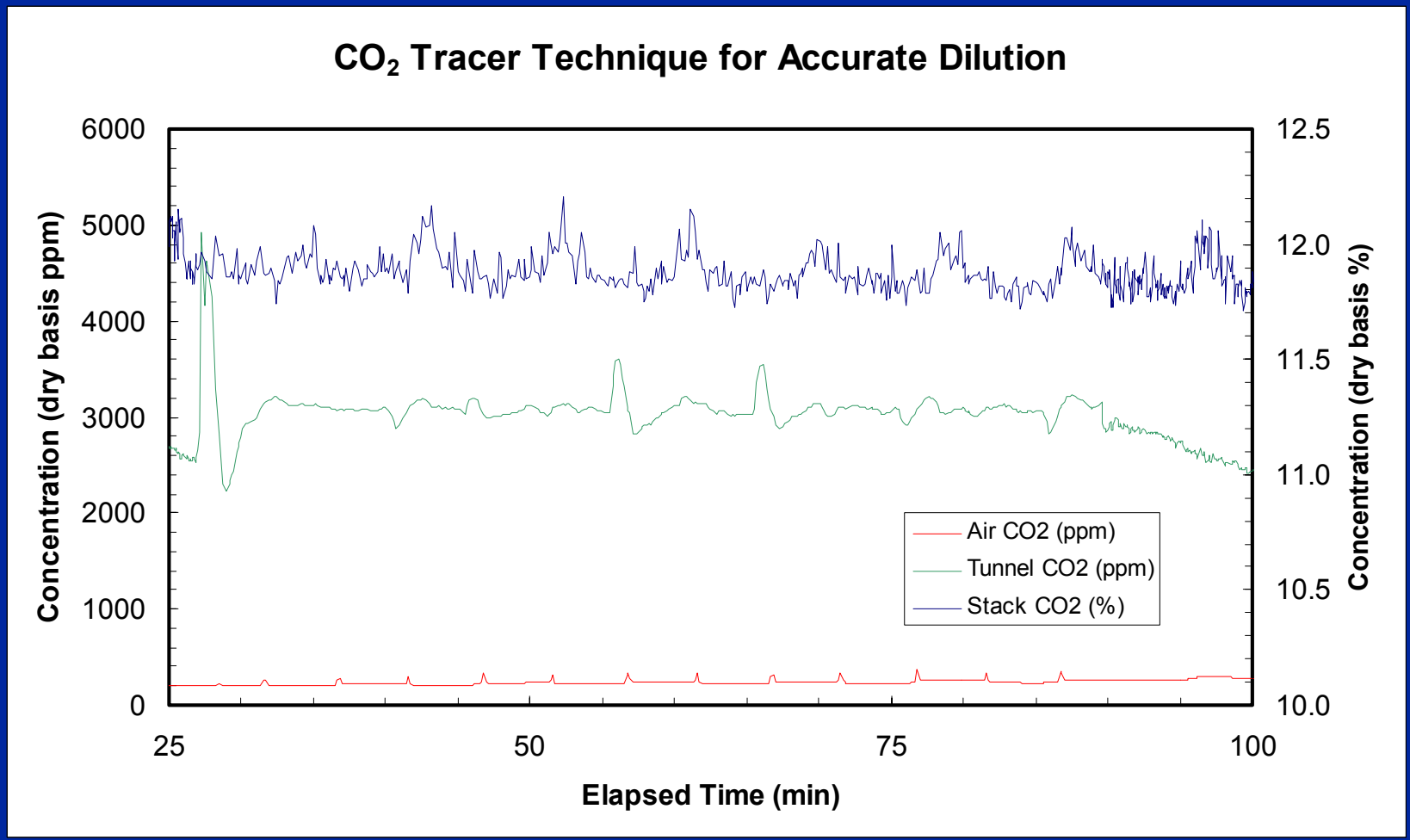

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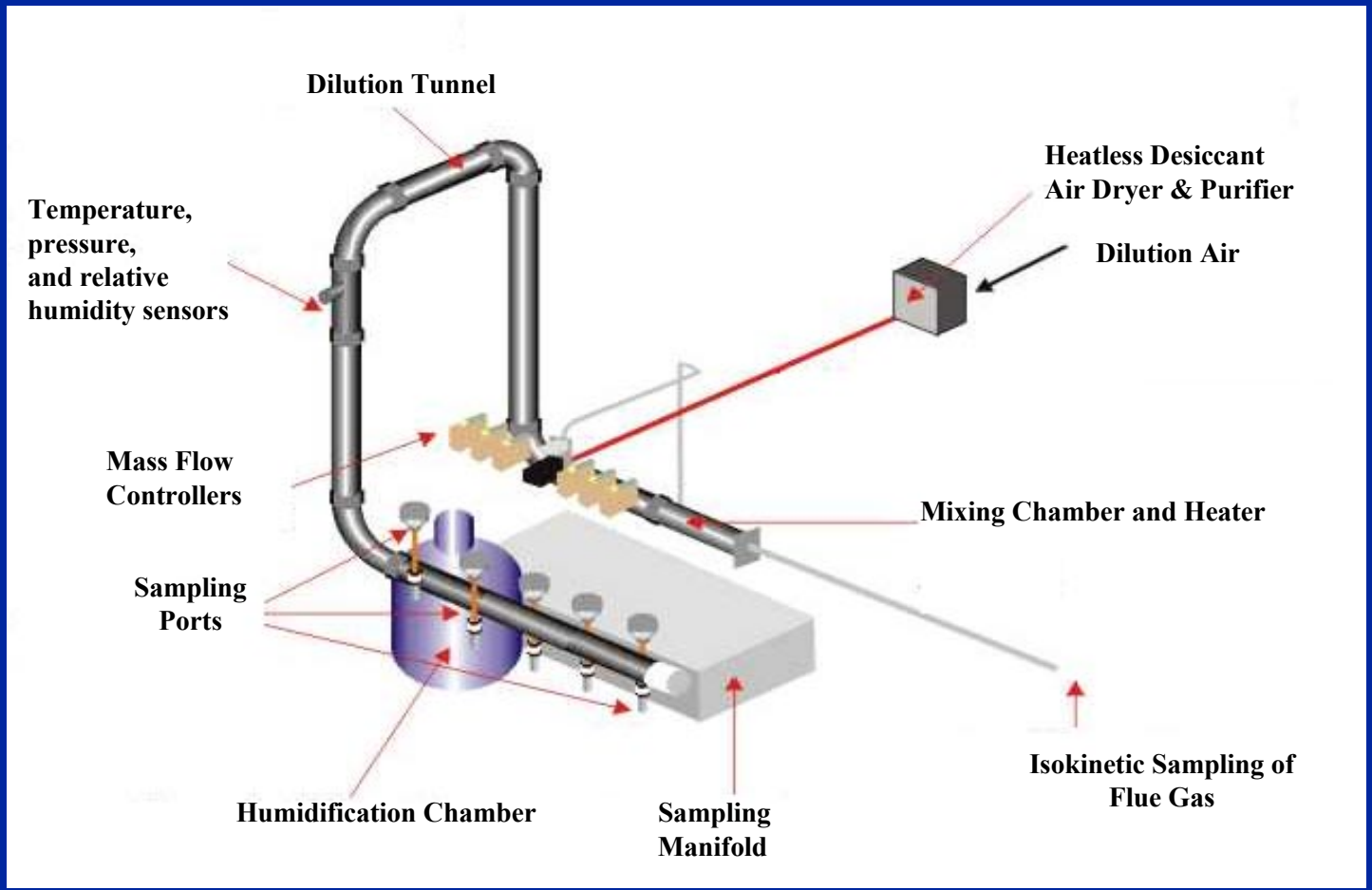
CETC Source Dilution Sampling System 1



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CETC Source Dilution System 2

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Teflon Surface Coating

Materials - DuPont PTFE
DuPont FEP

- Nonporous films
- Excellent chemical resistance
- Low friction
- Nonstick properties
- Liquid forms

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SO_2 Surface Loss Tests

	CETC 2	CETC 1
Relative Humidity	47%	48%
Inlet SO_2 Concentration	5.6 ppm	4.7 ppm
Residence Time	1 min	1 min
Sampling Interval	Continuous	5 min
#1	4.8% to 0%	9.3 % loss
#2	Loss within	5.9% loss
#3	20 min	0.9% loss

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NO_x Loss Tests

	CETC 2	CETC 1
Relative Humidity	47%	48%
Inlet NO_X Concentration	5.6%	5.8%
Residence time	1 min	1 min
Sampling interval	Continuous	Continuous
Loss	3.5% to 0% Within 15 min	6.1% to 0% Within 16 min

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System Capabilities

Parameters	CETC 1	CETC 2
Stack Velocity (m/s)	up to 3	up to 10
Tunnel Temperature (ºC)	18-40	18-40
Relative Humidity (%)	20-80	20-80
Dilution Ratio	40x	up to 100x
Residence Time (s)	15-25	40-80

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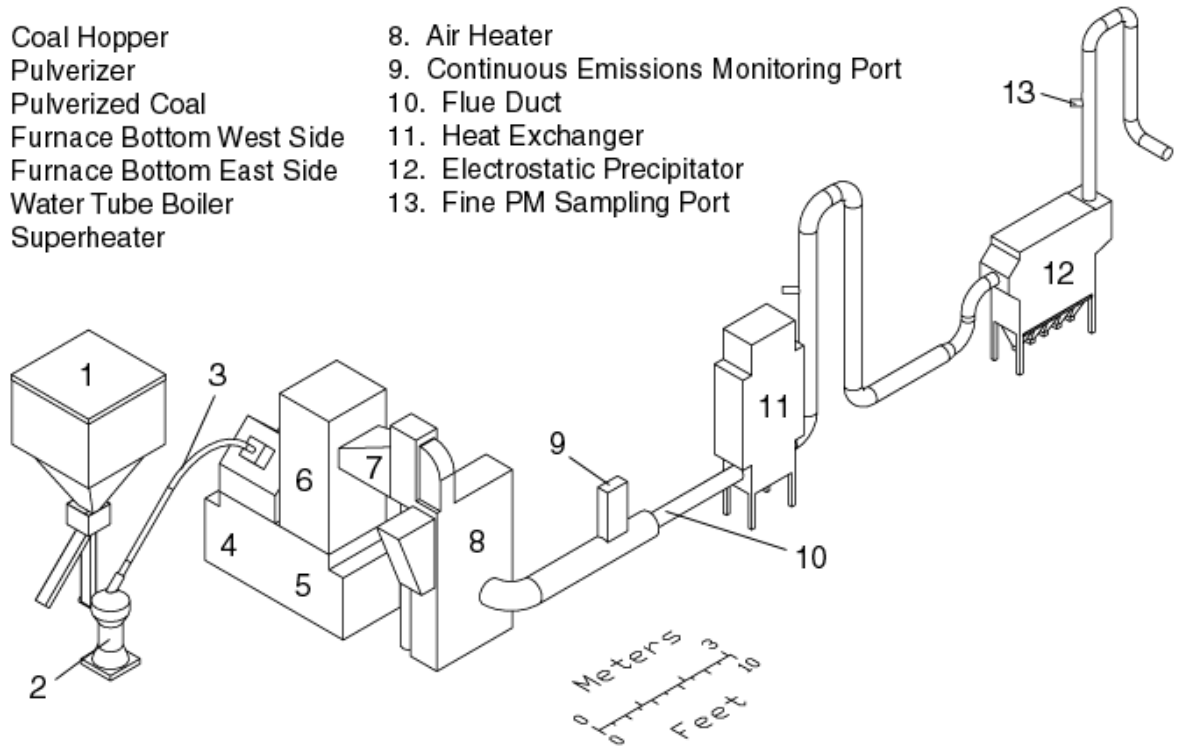
Schematic of Pilot-Scale Coal-Fired Boiler

1. Coal Hopper
2. Pulverizer
3. Pulverized Coal
4. Furnace Bottom West Side
5. Furnace Bottom East Side
6. Water Tube Boiler
7. Superheater
8. Air Heater
9. Continuous Emissions Monitoring Port
10. Flue Duct
11. Heat Exchanger
12. Electrostatic Precipitator
13. Fine PM Sampling Port



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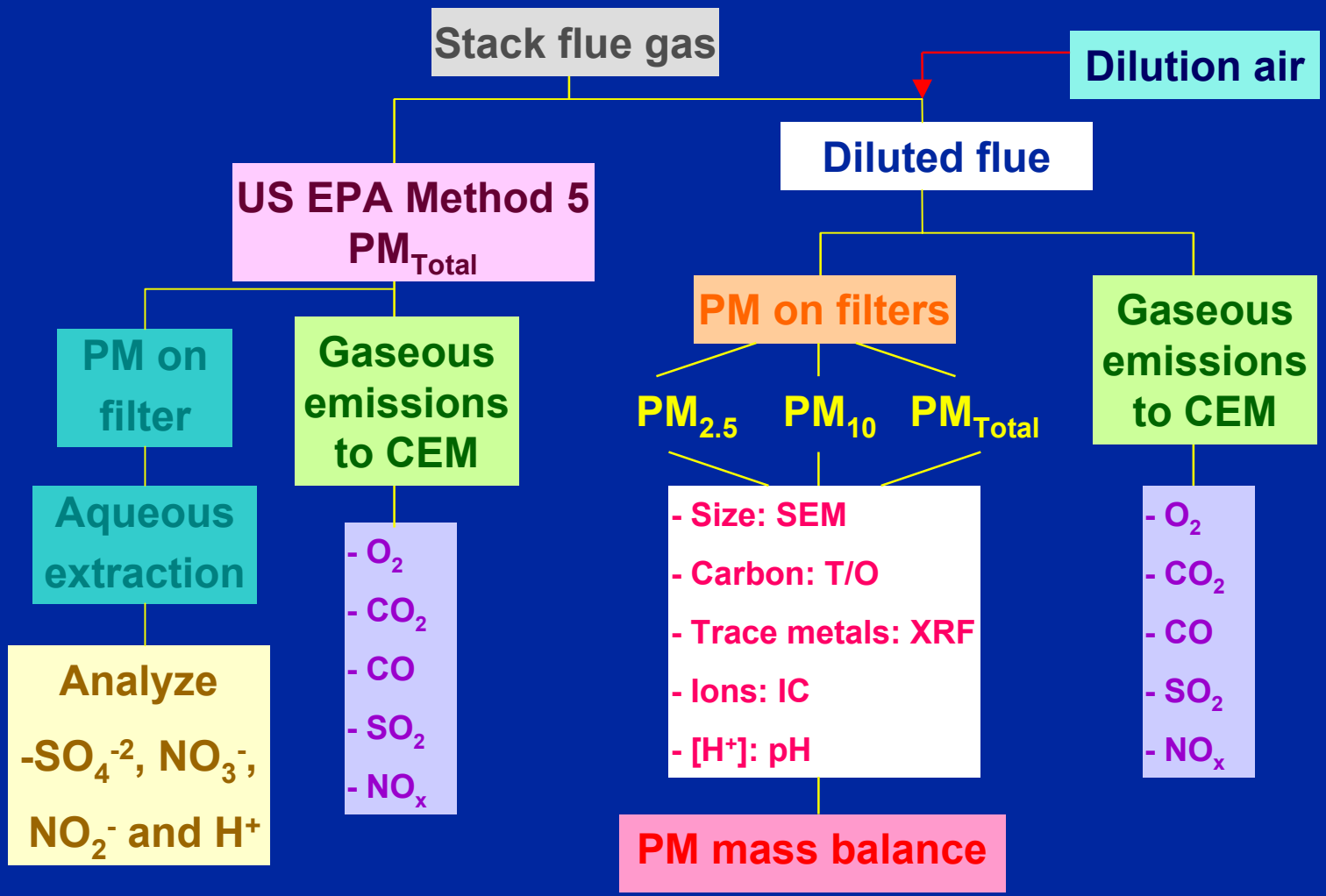
Sample Collection and Analysis Procedure



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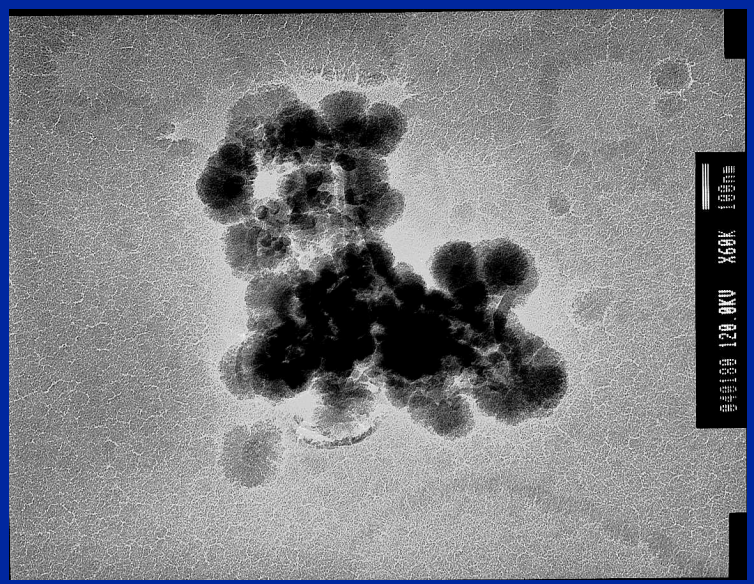
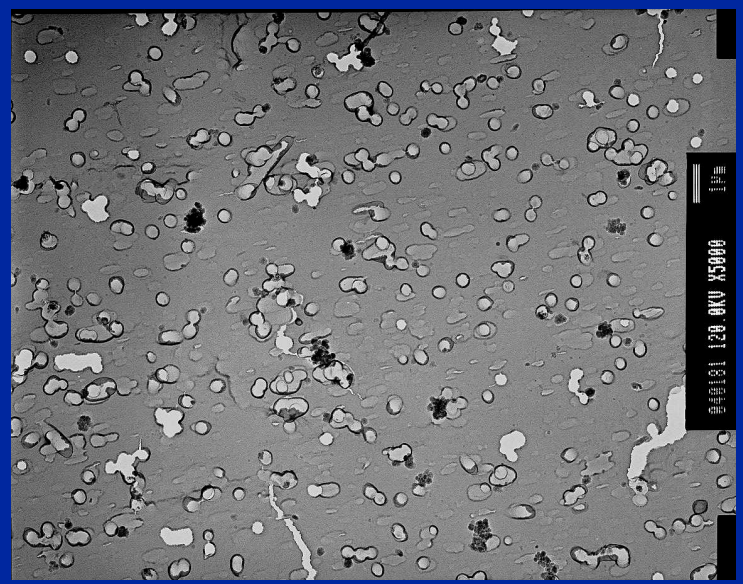
TEM Images – $PM_{2.5}$ Agglomerate for No. 2 Fuel Oil



X 60K



Field Image X 5K

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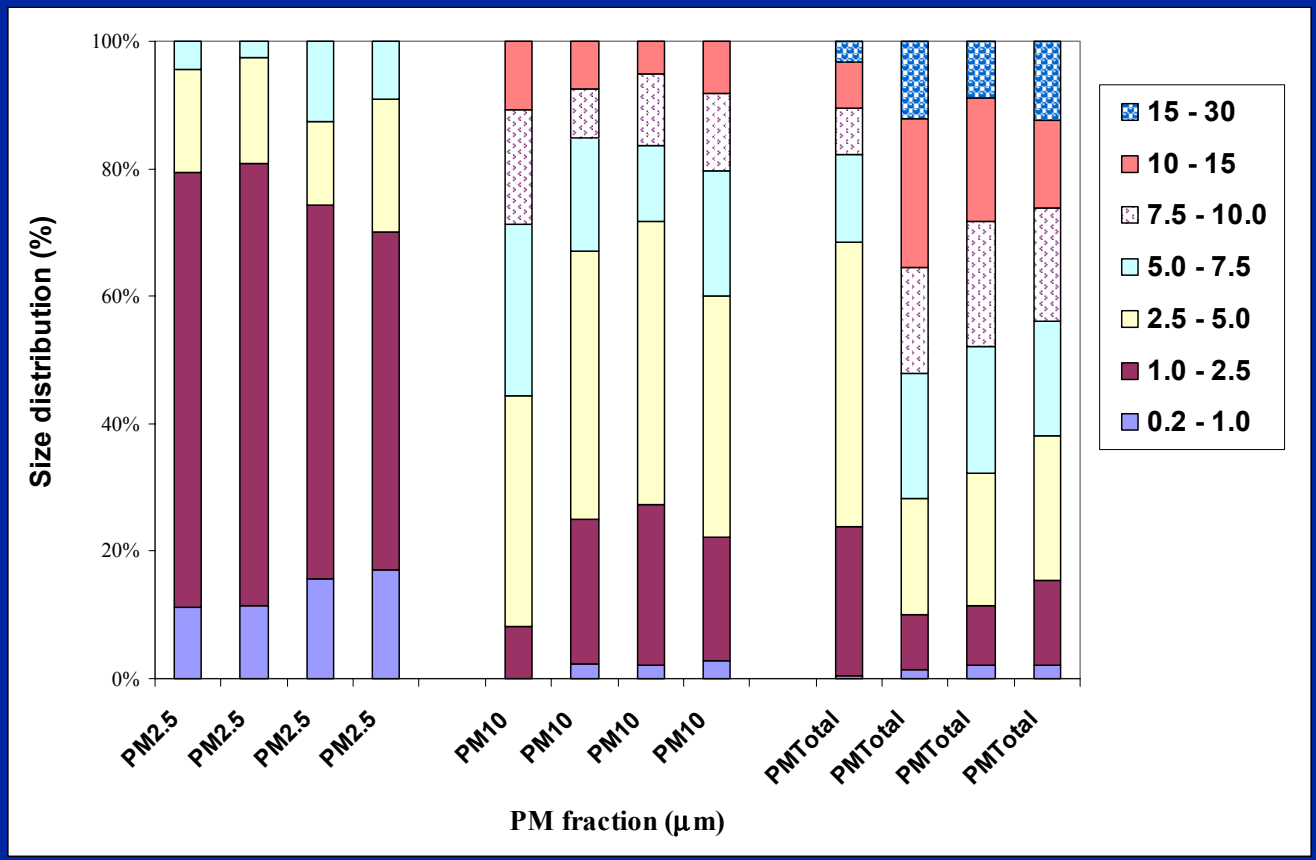
PM Size Distribution from No. 4 Fuel Oil Combustion

0.7% sulphur, 40% RH, 26x dilution



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PM mass loading for No.4 fuel (mg/cm^3) Trial Runs

Run	1	2	3	4	M5	RSD (%)
Loading						
$PM_{2.5}$, mg/m^3	61	62	62	63	NA	1.0
PM_{10}, mg/m^3	77	76	74	72	NA	2.8
PM_{Total}, mg/m^3	76	76	73	73	40	2.5
Insoluble Losses						
Probe, mg/m^3	3.9		3.8		2.5	1.8
Mixing Chamber, mg/m^3	5		11.6		NA	56.2
Filter Pack, mg/m^3	4.7		2.8		NA	35.8

RSD: Relative Standard Deviation

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Field suitability

8 Modules for portability

Light weight, surface coated Aluminum

Portable clean/dry air system

Data acquisition and control software

Adjustable support frame

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PM Mass Balance (mg/m^3)

40X dilution, 40% R.H.

Fuel		$PM_{2.5}$	PM_{10}	PM_{Total}
0.05% S Diesel 30 kW Boiler	Metal as oxides	0.03	0.02	0.02
	Organic carbon	0.71	0.71	0.68
	Elemental carbon	1.00	1.03	1.03
	Sulphate & Hydration	0.57	0.51	0.51
	By composition analysis	**2.31**	**2.27**	**2.24**
	By gravimetry	**1.93**	**2.09**	**2.09**
0.20% S #2 Fuel 30 kW Boiler	Metal as oxides	0.10	0.09	0.09
	Organic carbon	1.24	1.27	1.12
	Elemental carbon	0.69	0.73	0.76
	Sulphate & Hydration	4.69	4.90	5.76
	By composition analysis	**6.72**	**6.99**	**8.06**
	By gravimetry	**9.76**	**9.86**	**9.80**

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PM Mass Balance (mg/m^3) - Continued

40X dilution, 40% R.H.

Fuel		$PM_{2.5}$	PM_{10}	PM_{Total}
0.70% S #4 Fuel 130 kW Boiler	Metal as oxides	2.77	4.89	5.50
	Organic carbon	13.10	14.81	12.44
	Elemental carbon	4.22	11.65	14.27
	Sulphate & Hydration	10.10	10.73	12.73
	By composition analysis	**30.19**	**42.08**	**44.94**
	By gravimetry	**34.23**	**43.54**	**50.33**
0.23% S Bituminous C Coal 0.7 MW Boiler	Metal as oxides	31.00	86.00	99.00
	Organic carbon	3.00	4.00	4.00
	Elemental carbon	0.00	0.00	0.00
	Sulphate & Hydration	2.00	2.00	2.00
	By composition analysis	**36.00**	**92.00**	**106.00**
	By gravimetry	**38.00**	**77.00**	**91.00**

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Possible PM Losses

- Condensation at the probe tip inside the dilution tunnel
- Deposition on dilution tunnel surfaces (static, acids)
- Mixing zone losses (poor mixing, condensation, static)
- Deposition on filter pack (static)

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Data Validation

- Source dilution PM data scarce at present
- Urgent regulatory requirement and time constraints
- CANMET protocol still evolving and areas to verify
- Reproducibility and PM mass balance very good
- Will improve to reduce PM losses
- Calibration using particle generator
- Coal boiler and field testing this year

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Ongoing Work

- Further minimize system PM losses
- Incorporate flue splitter for stacks with velocity >10 m/s
- NH_3 introduction to the system
- Validate data
- Initial field trial before further modification of the system